Radioactive Decay and Pallet Artifacts in SPECT Imaging

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Our purpose is to discuss two types of corrections for count loss that occur while performing SPECT studies. These corrections will improve image quality. Radioactive decay correction should be considered with the development of new short-lived radiopharmaceuticals for SPECT imaging, such as technetium-99m (^{99m}Tc) HMPAO. The count rate is reduced by approximately 8.3% from radioactive decay of ^{99m}Tc during a standard 45-min SPECT acquisition. This can easily be corrected by multiplying each frame in the raw data by the decay factor. Count loss also occurs due to the attenuation of the pallet as the camera rotates under the patient. Pallet attenuation can be visualized and calculated by doing a 360° acquisition of a SPECT phantom filled with ^{99m}Tc. We have evaluated the attenuation from different manufacturer's pallets and head holders. There is as much as a 12.6% loss in count rate from the Siemens heavy-duty pallet and as little as 3.5% from the G.E. attachable head holder. A computer algorithm could be developed to correct for pallet attenuation, but the problem can be avoided by changing the system design for different types of SPECT acquisitions, especially when scanning the brain or heart. Some departments begin their SPECT acquisition in the posterior or lateral position and thereby compound the decay and pallet attenuation problems by causing the last few frames of the study to be acquired directly beneath the pallet where maximum attenuation will occur during maximum decay loss. Both the decay and pallet attenuation problems can combine to create as much as a 15%–20% loss of counts from the first to last image in a given ^{99m}Tc SPECT study.

We have investigated whether significant count loss occurs in SPECT studies due to either radioactive decay or pallet attenuation. Newer ^{99m}Tc radiopharmaceuticals, such as ^{99m}Tc HMPAO (Amersham) and ^{99m}Tc teboroxime (Squibb) and ^{99m}Tc sestamibi (Du Pont), are replacing radiopharmaceuticals with longer half-lives, such as iodine-123 (^{123}I) spectamine and thallium-201 (*1*). The six-hr half-life of these Tc radiopharmaceuticals will contribute to a significant count loss during longer SPECT acquisitions (*2*). With pallet attenuation and radioactive decay occurring simultaneously, the combined count loss during SPECT acquisitions may produce image nonuniformities and decrease image resolution (*3*).

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METHODS

Radioactive Decay Correction

The radioactive decay factor (DF) can easily be calculated for ^{99m}Tc during an average 45-min SPECT study.

$$\mathrm{DF} = e\,\frac{-0.693(45)}{360} = 0.917 \text{ or } 8.3\%$$

This shows that from ^{99m}Tc decay there is an approximate 8% count loss from the first frame to the last frame in a 45-min 360° SPECT acquisition. A simple decay correction program can be developed to correct for this count loss (Fig. 1). This simple program was rewritten to operate without user input by reading the image header to determine the time per view and number of frames required. Two operator inputs are required on the simplified version.

Notice the adjusted time per view in Figure 1. The total acquisition time includes the time between each view, which was 3 sec on our camera.

Pallet Attenuation

We determined the effect of pallet attenuation by using a cylindrical SPECT phantom with 25 mCi of ^{99m}Tc and a 360° SPECT acquisition at 40-sec per stop for 64 stops with a high resolution collimator (Fig. 2). The phantom was positioned

BASIC DECAY PROGRAM FOR Tc-99m

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This program corrects for Tc-99m decay
PROGRAM NAME:            DECAY MED
Adjusted Time per View:  Time view + ECT rotation time between views for step
                         and shoot acquisition

PRINT   'Enter adjusted time per view (in seconds)'
INPUT   T
PRINT   'Enter number of frames acquired'
INPUT   N
For: I = 1 to N          ! Do loop to cycle through each frame
                           frame (1 thru N).
T1 = T * I               ! T1 is the time elapsed at this frame.
D = 0.693*T1 21600       ! D is the decay constant.
D2 = EXP (D)             ! D2 is the decay factor.
CM D2,I                  ! Frame multiplied by decay factor.
Next I                   ! Go to next frame.
END
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FIG. 1. Simplified decay program.

so that two thirds of the phantom was on the pallet and one third was off the end of the pallet. This allowed us to assess pallet attenuation versus no attenuation in the same study (Fig. 3). The camera was set 8.5 cm from the surface of the phantom at 0, 90, 180, and 270° to ensure constant geometry during acquisition. The acquisition was started at 0°. A ^{99m}Tc point source was counted for one min over each pallet and head holder available in our department. The attenuated counts for each pallet and head holder were compared to the actual count of the same point source positioned at the same distance from the camera to calculate the percent of count loss due to attenuation.

RESULTS

Radioactive Decay Correction for ^{99m}Tc

Radioactive decay from ^{99m}Tc-based radiopharmaceuticals during a routine 45-min 360° SPECT acquisition results in an approximate 8% count loss from the first to the last frame. If the radioisotope concentration and distribution remain constant, as they do in a phantom, there will be a noticeable difference in the first and last frames when projection images are viewed in cine motion. When the projection images are reconstructed, this 8% count loss may not be translated into image artifacts on the reconstructed images, since this is a gradual count loss over a 45-min time period. However, when combined with pallet attenuation, the count loss does become significant (up to a 20% combined count loss on the aluminum heavy duty pallet). By correcting only for radioactive decay, an improvement can be seen in the reconstructed images (Fig. 4).

Pallet Attenuation

We evaluated the attenuation from three different pallets and one head holder. Regardless of the manufacturer, all pallets and head holders will have some degree of attenuation (*4*). Pallet construction and composition vary from one manufacturer to the next, depending on the weight capacity, dimensions, and materials selected. This causes a variation in the amount of attenuation observed. We analyzed a heavy duty pallet and medium duty pallet (Siemens Gammasonics, Schaumburg, IL) constructed of pressurized foam sandwiched between two layers of aluminum. A carbon fiber heavy duty pallet and carbon fiber head holder (General Electric Medical Systems, Milwaukee, WI) were also analyzed (Table 1).

We reconstructed the cylindrical SPECT phantom with solid sphere inserts. We used a low-pass cosine filter and applied Chang attenuation correction with a coefficient of 0.12. For display we set a window of 100 and a background threshold of ~60% in order to enhance the pallet artifact seen at the bottom of the image in Figure 4. This artifact is much more obvious and prominent in the non-decay-corrected transaxial images. Although it is still present on the decay-corrected image, it has been significantly reduced.

We have developed a cylindrical head holder (works-in-progress) that encompasses the patient's entire head and provides constant attenuation throughout the study (Fig. 5). This cylindrical head holder was designed in our laboratory with the same type of material used to construct the Siemens medium duty pallet. This device may help to absorb and decrease scatter, thereby improving the reconstructed image. By using this device, we were able to improve our resolution

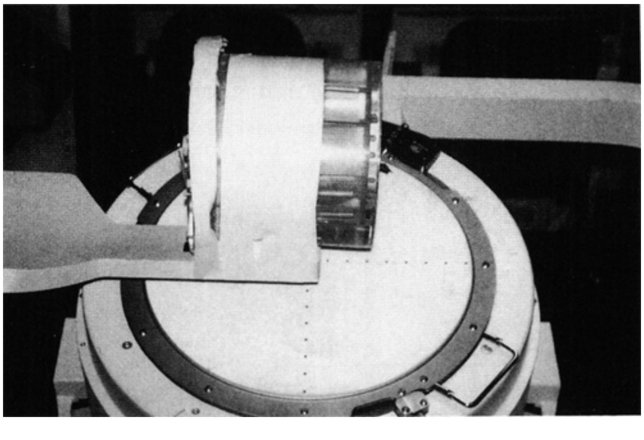

FIG. 2. SPECT phantom positioned so that one third was not attenuated by the pallet.

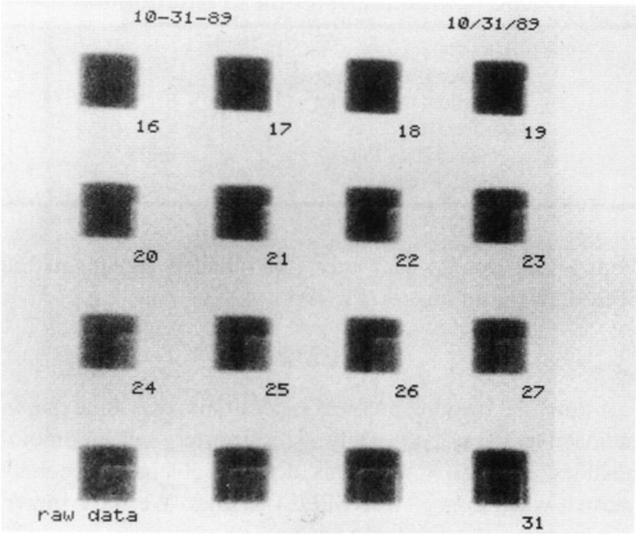

FIG. 3. Projection SPECT images of phantom on pallet showing effect of pallet attenuation.

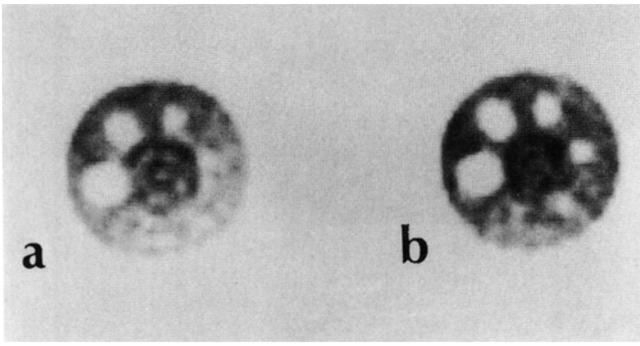

FIG. 4. (a) Non-decay-corrected transaxial slice of phantom and (b) decay-corrected transaxial slice of phantom.

TABLE 1. Count Loss due to Attenuation

Aluminum	
Heavy Duty Pallet	12.6%
Medium Duty Pallet	8.7%
Carbon Fiber	
Heavy Duty Pallet	6.8%
Head Holder	3.7%

from ~15.9 mm to 12.7 mm (the smallest sphere) in the SPECT phantom images (Fig. 6).

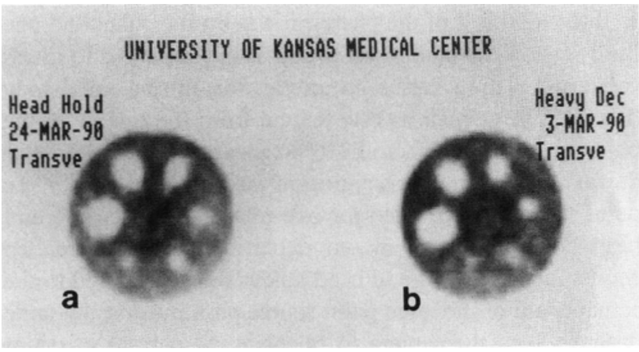

FIG. 6. (a) Cylindrical head holder transaxial slice of phantom and (b) transaxial slice of phantom resting on the pallet.

DISCUSSION

A potential imaging problem is count loss over time due to radioactive decay, especially with shorter half-life radionuclides, such as ^{99m}Tc. This decay problem is generally ignored when doing ^{99m}Tc SPECT studies. We have shown that by correcting for decay during a 45-min acquisition (8% count loss), significant image improvement can be seen on the reconstructed transaxial images.

Depending on the manufacturer and weight bearing capacity and materials used in pallets or other support devices, the attenuation alone may decrease the count rate by as much as 12%–14% (*5*). SPECT pallets introduce a non-uniform attenuation into all SPECT studies. Since we cannot eliminate SPECT pallets or head holders, we need to address other methods of correcting for this non-uniform attenuation.

There are currently no commercially available correction programs for pallet attenuation. Due to the wide range of SPECT studies that are performed on a pallet, it would require an extremely complicated program to accurately correct for pallet attenuation. Also, the program would have to calculate attenuation for a different set and number of pixels at each angle. The easiest way to correct for attenuation is to try to avoid it by using pallets that are designed with attenuation in mind.

A cardiac pallet could be designed with a cutout on the side where the patient's heart is located for a supine acquisition (Fig. 7). This pallet could be made of any type of material because any attenuation would be avoided. One manufacturer has developed a SPECT cardiac pallet (Siemens Medical Systems, Hoffman Estates, IL) made of a thin carbon fiber layer supported by a steel rod on the side of the pallet to support the patient's weight. The steel rod is not in the field of view during the cardiac acquisition. The aluminum pallets attenuate more than the carbon fiber pallets, therefore, the carbon fiber pallets should be used when available. It is important to know that the carbon fiber pallets may crack more easily and that the aluminum pallets are more durable when hit by a "stray" camera. One manufacturer has recalled a carbon fiber table due to cracking (*6*).

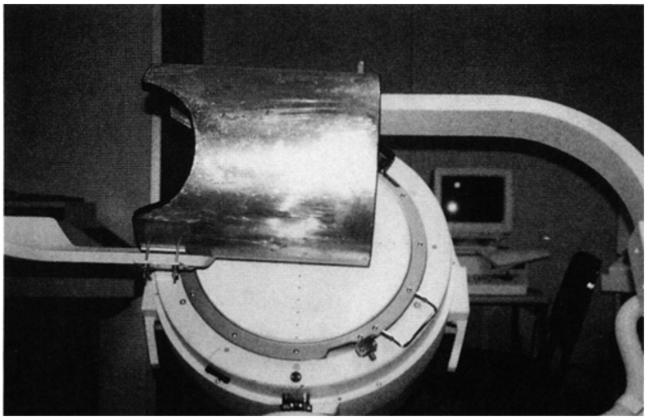

FIG. 5. A continuous attenuation device for head imaging.

The technologist should check the camera rotation around both sides of the pallet to make sure the pallet is centered properly. We recommend that commercially available head holders be utilized when doing SPECT head tomography since they are generally made of carbon fiber. Usually, the head holder allows close positioning to the patient, improving resolution. Another way to decrease attenuation is to switch to the lighter duty pallet when the size of the patient permits.

Since the introduction of a non-uniform attenuator during acquisition causes artifacts, one possible answer to pallet attenuation is to provide a consistent source of attenuation around the patient. We are currently working with the specially designed 360° cylindrical head holder shown in Figure 5. It encompasses the patient's entire head and therefore provides constant attenuation throughout the entire SPECT study.

Technologists should avoid ending the SPECT acquisition directly under the pallet if these decay and pallet corrections are not implemented. By positioning the camera so that the pallet appears in the early part of the acquisition (starting at 90° and rotating clockwise), an increased count loss can be avoided due to maximum decay during pallet attenuation.

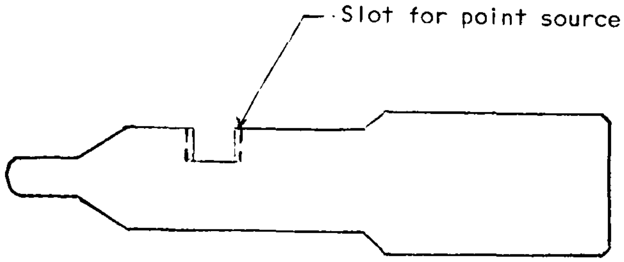

FIG. 7. Heart imaging SPECT pallet for spine 180° acquisition (viewed from above) shows the slot for the point source used to position the heart in the cutout area.

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